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Experimental Investigation on the dynamic properties of AlSi10Mg produced by Selective laser melting technique

Bar Nurel[1], Moshe Nahmany[2,3], Adin Stern[3], Nahum Frage[3] and Oren Sadot[1]

[1]Depr. of Mechanical Engineering, Ben Gurion University of the Negev, Israel.
[2]Dept. of Materials, Nuclear Research Center - Negev, Israel.
[2]Dept. of Materials, Ben Gurion University of the Negev, Israel.

1. Abstract

Additive Manufacturing (AM) method by Selective Laser Melting (SLM) of metals has attracted the industry attention due to its many advantages. SLM method based on focusing laser beam to selectively melt thin layers of metal powder that create eventually complex parts.
This research investigated the effect of different building orientations and different heat states on the dynamic properties of the AM-SLM AlSi10Mg alloy. The investigation carried out by the Split Hopkinson Pressure Bar system.
The strain-rates for the dynamic properties were in range of 700 s^{-1} ÷ 7900 s^{-1}. The dynamic properties were found to be influenced by the different orientations in contrast to earlier studies.

Keywords: Additive manufacturing, AlSi10Mg, Dynamic properties, Selective laser melt, Split Hopkinson Pressure Bar,

2. Introduction

Split Hopkinson Pressure Bar (SHPB) is a standard experimental system for measuring stress-strain curve at various relative high strain rates. Today, the information about mechanical properties for various materials at quasi-static state is vast with respect to the dynamic properties. One of the common tool to investigate the dynamic mechanical properties is the SHPB system. The SHPB system consists of two bars, holding the sample being tested, a striker and a striker accelerator. In our system, the striker is accelerated by the gas gun towards the first bar at a speed range of 12-30 m/s. As a result of the impact, a compression wave develops in the system bars. A schematic configuration of the system is depict is Figure 1(a). Figure 1(b) demonstrates x-t diagram of the waves traveled in the bars. The sample stress-strain cure is generated from the measured elastic deformations of the bars - marked S.G in figure 1(a). A typical strain measurement is presented in Figure 1(c).

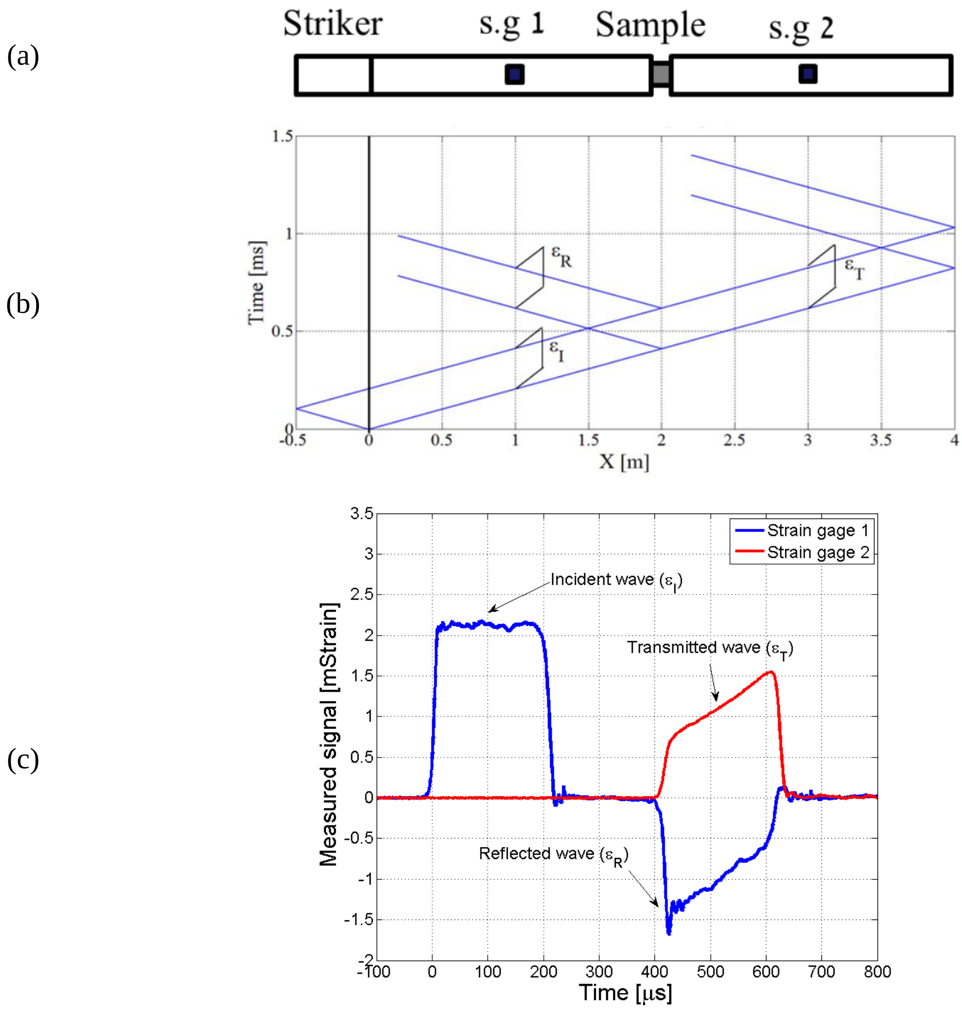

Figure 1 : a) Scematic configuration of SHPB system. b) Wave propogation through the bar. c) typical strain mesurment.

Based on one dimensional assumption, strain and strain-rate are calculated using equations (1)-(3) [1]:

$$\dot{\varepsilon}_s(t) = \frac{2C_{0B}}{H_s}\varepsilon_R(t) \tag{1}$$

$$\sigma_s(t) = \frac{E_B A_B}{A_s}\varepsilon_T(t) \tag{2}$$

$$\varepsilon_s(t) = \int \dot{\varepsilon_s}(t)dt = \frac{2C_{0B}}{H_s}\int \varepsilon_R(t)dt \tag{3}$$

Suffix ***s*** denotes sample; ***B*** denotes bar (bar) properties; and ***R*** and ***T*** denote the reflected and transmitter bars as explained in Figure 1(c). C [m/s] denotes acoustic velocity; H_s [m] is the sample length; E [GPa] denotes Young's modulus; A [m^2] represents area of contact; $\boldsymbol{\varepsilon_R}$ and $\boldsymbol{\varepsilon_T}$ denote strains as a function of time. In order to convert those engineering values to true values equations (4)-(6) is implemented [2]:

$$\text{True } \dot{\varepsilon}_s(t) = \frac{\dot{\varepsilon}_s(t)}{1-\varepsilon_s(t)} \quad (4)$$

$$\text{True } \sigma_s(t) = \sigma_s(t)\cdot\left(1-\varepsilon_s(t)\right) \quad (5)$$

$$\text{True } \varepsilon_s(t) = -\ln\left(1-\varepsilon_s(t)\right) \quad (6)$$

Over the last decade, additive manufacturing (AM) by Selective Laser Melting (SLM) of metals has attracted substantial attention due to its capabilities of producing complex part where traditional machining fails to do so. Aluminum alloys have drawn the attention of SLM community because of the widespread use of such alloys across many areas, such as aerospace and automotive industry [3]. AlSi10Mg alloy have already been demonstrated to perform well with SLM. Rosenthal et al. [4] investigated the mechanical properties of this alloy at quasi-static strain-rate range of $2.7\cdot10^{-6}$ s^{-1} ÷ $2.7\cdot10^{-1}$ s^{-1} while Zaretsky et al. [5] investigated the dynamic properties at strain-rate range of 5000 s^{-1} ÷ 100,000 s^{-1}. No reported data were found concerning dynamic properties of AM-SLM AlSi10Mg for strain rate between $2.7\cdot10^{-1}$ s^{-1} ÷ 5000 s^{-1}. Therefor the aim of the present study is to investigate the dynamic mechanical properties of AM-SLM AlSi10Mg alloy at strain-rate range of 700 s^{-1} ÷ 7900 s^{-1} and studying the effect of different orientation and heat state on these dynamic mechanical properties.

AM-SLM AlSi10Mg rods were built in both directions, Z and X, from a pre-alloyed AlSi10Mg powder, using EOS-280 system. Stress-relief was performed to half of the samples (T5 heat treatment (HT): 300ºc, 2h). Disks (samples) were machined from those rods, 7 mm in diameter and 3.5 and 7 mm heights, as shown in Figures 2a and 2b, with the ability to achieve different strain rates.

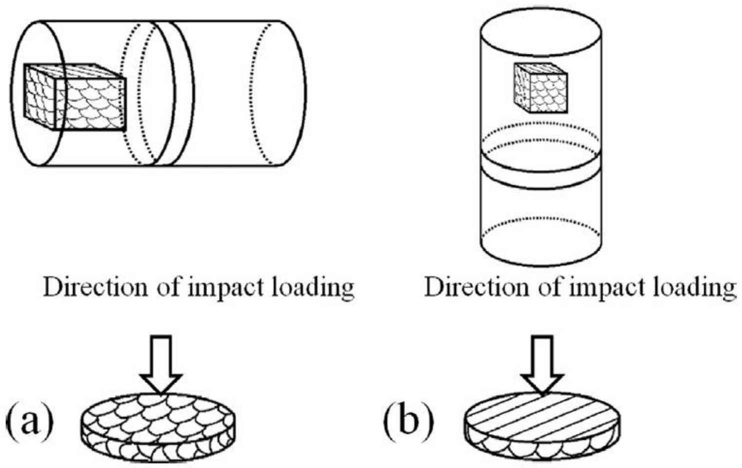

Figure 2: Sample preparation from rods in two different orientation. a) X direction. b) Z direction. Taken from [5].

The results for the true-stress true-strain curves are depict in Figure 3. A magnifications of some relevant regions in the curves are inserted too in Figure 3. The magnifications emphasize the different properties of the tested samples for samples that experience heat treatment and samples in the as-build stats at strain value of 0.1 in different manufacturing orientation.

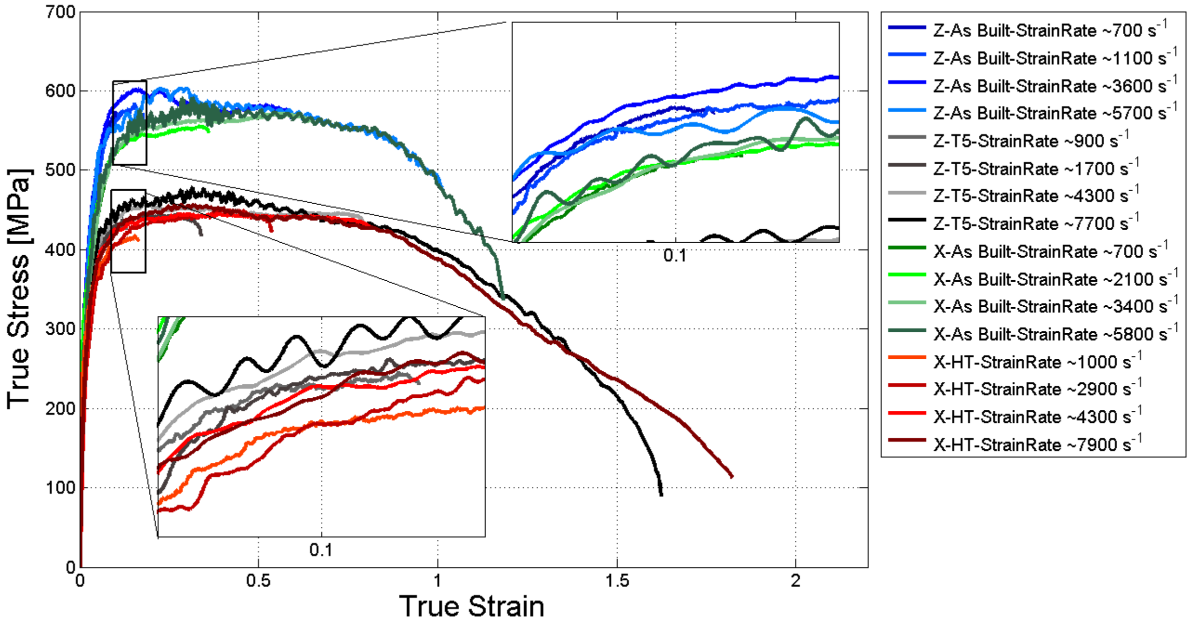

Figure 3: A summury of True-stress True-strain curves at variuse strain-rate for both X- and Z-oriented samples with two different heat treatments (As-build and T5).

Closer examination of the tested samples reveals that X-oriented samples had become ellipse in shape in contrast to the Z-oriented samples that conserved there rounder disk shape. These results suggest that different oriented building direction affect the un-isotropic nature of the sample. Elaboration on this subject will be given in the talk.

References

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